THE DINANTIAN *TAPHROGNATHUS TRANSATLANTICUS* CONODONT RANGE ZONE OF GREAT BRITAIN AND ATLANTIC CANADA

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ABSTRACT. The *Taphrognathus transatlanticus* Range Zone is proposed to replace the earlier defined, and subsequently rejected, *Taphrognathus varians–Cavusgnathus–Apatognathus* Assemblage Zone. It is based on the occurrence and range of the conodont species *Taphrognathus transatlanticus* sp. nov. in strata of Viséan age on both sides of the Atlantic Ocean.

The *T. transatlanticus* conodont Range Zone is present in the upper part of the S_2 Zone of the Avon Gorge in Great Britain and the lower B Subzone of the Windsor and Codroy groups of Atlantic Canada. The B Subzone has previously been correlated with the S_2 (Sub)zone using megafaunal and microfloral criteria; the stratigraphically restricted occurrence of *T. transatlanticus* sp. nov. supports these correlations. The B Subzone has previously been correlated with the middle late Viséan using foraminifera and algal microflora but we suggest that it is middle Viséan in age. Our suggestion is supported by previous megafaunal correlations. The upper S_2 Zone and the lower B Subzone have both been correlated with the Holkerian Stage of the British Dinantian. The fauna of the *T. transatlanticus* conodont Range Zone has not yet been found at the boundary stratotype section of the Holkerian at Barker Scar, Cumbria.

THE *Taphrognathus varians–Cavusgnathus–Apatognathus* Assemblage Zone of Great Britain was defined by Rhodes *et al.* (1969, p. 43) who based it on the stratigraphic range of the conodont *Taphrognathus varians* Branson and Mehl in the upper part of the S_2 Subzone of the Avon Gorge (Samples S45 to S58), despite the fact that *T. variaus* had (and has) not been found in the Avon Gorge. The conodonts assigned to *T. varians* by Rhodes *et al.* (1969, pl. 13, figs. 4, 5) came from Harden Burn, Roxburghshire, but the authors did note (p. 43) that 'specimens transitional between *Cavusgnathus* and *Taphroguathus* . . . have been found in this assemblage zone'. Von Bitter (1976, p. 231) reported the occurrence of *Taphrognathus* sp. in the Lower Windsor Group of Nova Scotia and observed them to be practically identical to the transitional specimens illustrated by Rhodes *et al.* (1969, pl. 13, figs. 1–3). The same species has been recovered from the Lower Windsor Group correlative, the Lower Codroy Group of south-western Newfoundland (von Bitter and Plint-Geberl 1979, 1982). On the basis of the rather well-defined and consistent stratigraphic distribution of the species over an extensive area, von Bitter and Plint-Geberl (1979, 1982) defined the *Taphrognathus* Zone and correlated it with the lower B Subzone of the Windsor Group, as designated by Bell (1929) on macrofaunal evidence.

Re-examination of the Avon Gorge collections of Rhodes *et al.* (1969), as well as examination of additional specimens from that locality recovered in 1981 by Mr. Julian Pearce working under the direction of the second author at the University of Southampton, verifies that *Taphroguathus* sp. of von Bitter (1976) and *Taphrognathus* n. sp. A of von Bitter and Plint-Geberl (1979, 1982), rather than *T. varians* Branson and Mehl, is present and moderately common in the Avon Gorge section. We name this new species *Taphroguathus transatlanticus* sp. nov.

Austin and Mitchell (1975, pl. 1, figs. 5, 6, 16, 18, 19, 30) reported *T. variaus* from the upper division of the Lower Carboniferous Shale of County Tyrone, Northern Ireland, but this is a lower stratigraphic level than that from which *T. transatlanticus* sp. nov. has been recovered. We agree with Higgins and Varker (1982, p. 154) that the occurrences of *Taphrognathus* sp. and *Taphroguathus* n. sp. A (both = *T. trausatlauticus* sp. nov. of this study) of von Bitter (1976), von Bitter and Plint-Geberl

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(1979, 1982), and Plint-Geberl (1981), as well as the new occurrences in Great Britain and Atlantic Canada reported here, are all geologically younger than the *Taphrognathus* Zone of Ravenstonedale, Great Britain. The older faunas probably fall within the range of *T. varians* as recorded in North America by Sandberg (1979) and in England by Metcalfe (1981).

The absence of *T. varians* from the Avon Gorge strengthens our conviction that the specimens from that locality, as well as the taphrognathids from Atlantic Canada, do not represent juvenile individuals of a species of *Cavusgnathus* (as initially suggested by Rhodes and Austin 1970, p. 334, and subsequently reinterpreted by Austin 1973*a*, p. 527). The appearance of these unusual taphrognathids in a single narrow stratigraphic interval of lithologically diverse rocks which represent a wide range of environments on both sides of the Atlantic, suggests that the *Taphrognathus* Assemblage Zone of von Bitter and Plint-Geberl (1982) in Atlantic Canada and the *T. varians–Cavusgnathus–Apatognathus* Assemblage Zone in the Avon Gorge are the same zone and are time equivalent. This conclusion necessitates resurrection and redefinition of the zone originally recognized by Rhodes *et al.* (1969) but later supressed by Austin (1973).

THE *TAPHROGNATHUS TRANSATLANTICUS* CONODONT RANGE ZONE

1969 *Taphrognathus varians–Cavusgnathus–Apatognathus* Assemblage Zone; Rhodes *et al.* p. 43.
1982 *Taphrognathus* Assemblage Zone; von Bitter and Plint-Geberl, p. 206.
non 1982 *Taphrognathus* Partial Range Zone; Higgins and Varker, p. 153.

Characteristic species. *T. transatlanticus* sp. nov.; in the Avon Gorge, Great Britain, associated with *Cavusgnathus windsorensis* Globensky and other species listed in Tables 1 and 2; in Newfoundland,

TABLE 1. Distribution of conodonts at locality 1, the *Taphrognathus transatlanticus* Zone of the Avon Gorge, Great Britain. Collections are those studied by Rhodes *et al.* (1969) and identifications other than those of the first two taxa are by R.L.A. Figured specimens deposited at the British Museum (Natural History). Unfigured specimens deposited at the Department of Geology, University of Southampton.

SAMPLE CODE AND WEIGHT OF SAMPLE PROCESSED (IN KILOGRAMS)					
S 45 8 kg	S 49 7·5 kg	S 53 7 kg	S 54 3 kg	S 58. 7·5 kg	
–	4^{xxx}	6^{x}	1	3	Taphrognathus transatlanticus sp. nov., Sp element
16	15^{xx}	–	1	–	Cavusgnathus windsorensis Globensky, Sp element
4^{xxxx}	57	–	–	–	Cavusgnathus unicornis Youngquist & Miller, Sp element
–	1	–	–	–	Cavusgnathus charactus Rexroad, Sp element
–	18	–	1^{xx}	–	Cavusgnathus sp., dextral Sp element
3	–	1	–	–	Spathognathodus campbelli Rexroad, Sp element
–	–	1	–	–	Spathognathodus scitulus (Hinde), Sp element
6	20	–	–	–	Hindeodus cristulus (Rexroad), Sp element
1	–	–	1	–	Hindeodus sp., Sp element
–	1	1	–	–	Apatognathus sp.
–	1	–	–	–	Unidentified plectospathodiform element
–	1	–	–	–	Unidentified ligonodiniform element
2	10	–	–	–	Unidentified Hi element
1	9	–	–	–	Unidentified Ne element
1	3	1	–	–	Unidentified Oz element
2	3	2	–	–	Unidentified Tr element
1	3	–	–	–	Genus & species indeterminate

x One fragmentary specimen. xx One specimen doubtful. xxx Three of the specimens were figured by Rhodes et al. (1969, pl. 13, figs. 1–3) and deposited in the British Museum (Natural History). xxxx Two of these specimens appear to be transitional with Taphrognathus transatlanticus sp. nov.

Canada, associated with the species listed in Tables 3 and 4; in Atlantic Canada, *C. windsorensis* is exceedingly rare in this zone.

Limits. The limits of this range zone coincide with the stratigraphic range of *T. transatlanticus* sp. nov., as known in the Avon Gorge of Great Britain and the Lower Codroy and Windsor groups of Atlantic Canada. In Atlantic Canada the zones above and below are respectively the *Cavusgnathus* and *Diplognathodus* Zones of von Bitter and Plint-Geberl (1982). These zones have yet to be recognized in Britain, although in both Britain and Canada examples of the genus *Cavusgnathus* appear earlier than *T. transatlanticus* sp. nov.

Distribution. In Great Britain this range zone is present in the upper part of the S_2 Subzone of the Avon Gorge (Tables 1 and 2) and has been identified by the authors in a mid-Dinantian fauna reported by Davies (1980) from an isolated sample collected near Trefil, South Wales (O.S. 1:50,000 Sheet 161, SN 120125).

In Atlantic Canada *T. transatlanticus* sp. nov. and conodonts indicative of this range zone have been identified from the provinces of Nova Scotia, Newfoundland, and Quebec at the localities listed and described in the Appendix. In Nova Scotia the range zone is known from the lower part of the B Subzone of the Lower Windsor Group (von Bitter 1976; Dudar 1980; R. Dhindsa, in prep.). In southwestern Newfoundland it has been recognized in the Lower Codroy Group on Fischells and Barachois brooks, as well as in several complex stratigraphic sequences south of Codroy (Tables 3 and 4; von Bitter and Plint-Geberl 1982). In Quebec it is present in two areas of Lower Windsor Group strata on the Magdalen Islands (Plint-Geberl 1981).

Correlation. Rhodes *et al.* (1969, pp. 43, 44) concluded that specimens of the species here identified as *T. transatlanticus* sp. nov. were identical to those illustrated and designated as *Taphrognathus–Cavusgnathus* transitions by Rexroad and Collinson (1963, pl. 1, figs. 21, 23–25) from the St. Louis Limestone. We have not seen the latter material and we are uncertain as to whether the Rexroad and Collinson specimens are *T. transatlanticus* sp. nov. We agree they are similar and note that the

TABLE 2. Distribution of conodonts at locality 1, the *Taphrognathus transatlanticus* Zone of the Avon Gorge, Great Britain, based on conodont collections made by Mr. Julian Pearce, University of Southampton. Identifications of all taxa other than *T. transatlanticus* sp. nov. and *Cavusgnathus windsorensis* by R.L.A. All specimens deposited at the Department of Geology, University of Southampton.

AG I	AG H	AG G	AG E	AG D	AG C	AG B	AG A	
-	-	-	1	-	-	-	-	Cavusgnathus charactus Rexroad, Sp element
-	-	-	1	1	2	3	-	Cavusgnathus sp., Sp element
-	-	-	-	1	-	-	-	Cavusgnathus unicornis Youngquist & Miller, Sp element
1	2	-	-	-	-	-	-	Cavusgnathus windsorensis Globensky, Sp element
-	1	-	-	-	-	-	-	Unidentified Tr element
1	1	-	-	-	-	-	-	Ozarkodina compressa Rexroad, Oz element
1	1	-	-	-	-	-	-	Unidentified Oz element
-	-	1	-	-	-	-	-	Spathognathodus sp., Sp element
-	1	1	2	-	-	1	-	Taphrognathus transatlanticus sp. nov., Sp element
-	3	-	-	-	-	-	-	? Angulodus sp.
2	3	-	2	-	-	-	-	Genus and species indeterminate
3·24	2·28	0·92	0·53	2·97	0·70	1·71	1·68	Weight of sample broken down (kg)

American species, like *T. transatlanticus* sp. nov., is limited to a very narrow stratigraphic interval, falling in the upper Lower St. Louis Formation and the lower Upper St. Louis Formation (ibid., table 1). Although the zone defined by the occurrence of this species was not defined by Rexroad and Collinson (1963), it would not be unreasonable to expect it to correlate with the *T. transatlanticus* Range Zone. Rather than correlating the *T. varians–Cavusgnathus–Apatognathus* Zone tentatively with the Lower St. Louis Formation, as was done by Rhodes *et al.* (1969), we would tentatively correlate the redefined zone with the middle of the St. Louis Formation.

Higgins and Varker (1982) concluded that the association of *Cavusgnathus* spp. with *Taphrognathus* sp. reported by von Bitter (1976) from Nova Scotia probably indicated a younger age for these occurrences than for the *Taphrognathus* Zone of Ravenstonedale, Great Britain. The presence of *Cavusgnathus* spp. in only younger strata and the mutual exclusivity of species of *Cavusgnathus* and *Taphrognathus* at Ravenstonedale (Higgins and Varker 1982, text-figs. 6–8), the mutual occurrence of species of *Cavusgnathus* with *T. transatlanticus* sp. nov. in the Avon Gorge and in Atlantic Canada (Tables 1–4), and previous correlations made by Bell (1929) and Utting (1980) and discussed in the section that follows, cause us to agree with Higgins' and Varker's conclusions.

Conil *et al.* (1976*a*, table 11; 1976*b*, Enclosure 2) have indicated the presence of *Taphrognathus* in Zone V2a of Belgium. The species illustrated has not been examined but may be *T. transatlanticus* sp. nov.

Bell (1929, p. 71) used megafaunal criteria to correlate the B Subzone of the Lower Windsor Group of eastern Canada with the S_2 (Sub)zone of the Avon Gorge of Great Britain. Lewis (1935) could not correlate Lower Windsor Group strata with that of the Avon Gorge since he lacked corals from the Lower Windsor Group. He did, however, correlate the Upper Windsor Group with the upper *Dibunophyllum* (Sub)zone, the megafaunal zone overlying the S_2 Zone in the Avon Gorge. Finally,

TABLE 3. Distribution of conodonts at localities 2, 3, and 4 (see Appendix), the *Taphrognathus transatlanticus* Zone, area B of von Bitter and Plint-Geberl (1982), south-western Newfoundland, Canada. Identifications by von Bitter and Plint-Geberl (1982). All specimens deposited at the Royal Ontario Museum, Toronto.

Fish -1-1	Fish -1-2	Fish -1-3	Fish -1-4	Fish -1-6	Fish -1-7	Fish -1-8	Fish -1-9	Fish -1-10	Corm -1-1	Corm -1-2	Corm -1-3	Corm -1-4	Bara -1-1	Bara -1-2	
-	-	-	-	1	-	-	2	-	-	-	-	-	3	6	? Bispathodus spp.
16	-	-	-	-	-	-	-	-	-	-	-	-	6	-	Spathognathodus sp. nov.A
-	-	-	-	-	-	-	-	-	-	-	-	-	7	-	Spathognathodus campbelli
1	1	-	-	1	3	1	-	-	-	-	-	-	-	-	Cavusgnathus regularis type, Sp element
-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	Cavusgnathus regularis type, Oz element
1	-	-	-	-	1	-	-	-	-	-	-	-	-	-	Cavusgnathus regularis type, Ne element
5	2	5	1	-	1	13	4	1	5	2	-	7	11	2	Taphrognathus transatlanticus sp. nov., Sp element
1	-	-	-	-	-	-	-	-	-	-	1	-	3	-	Taphrognathus transatlanticus sp. nov., Oz element
-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	Taphrognathus transatlanticus sp. nov., Pl element
-	-	-	-	-	-	-	-	-	-	1	2	-	-	1	Taphrognathus transatlanticus sp. nov., Tr element
-	-	-	-	-	-	1	-	1	-	-	-	-	-	-	Unidentified Oz element
-	-	-	-	-	-	-	-	-	-	-	-	-	5	-	Unidentified Hi element
3	-	-	-	-	2	-	1	-	-	-	-	-	-	-	Unidentified Tr element
1	-	3	-	-	1	-	-	-	-	-	-	-	4	3	Unidentified Hi element
-	-	-	-	-	4	-	-	2	-	-	-	-	3	1	Genus and species unidentified
-	-	-	-	-	-	-	-	-	-	P	-	P	-	P	Vertebrate remains
2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	Weight of Sample processed (kg)
.93	1·22	.96	1·21	1·06	.95	1·62	1·75	1·27	1·91	1·98	1·96	1·95	2·00	1·23	Weight of Sample broken down (kg)

Utting (1980) correlated that part of his miospore zone I occurring in the B Subzone of the Lower Windsor Group with the S_2 macrofaunal zone of Great Britain. Our discovery of the stratigraphically restricted species *T. transatlanticus* sp. nov. in the S_2 Zone of the Avon Gorge and the lower B Subzone of Atlantic Canada strengthens the correlation made by Bell (1929) and Utting (1980).

Bell (1929) believed the B Subzone of the Lower Windsor Group to be of middle Viséan age, a point of view apparently shared by Giles (1981), but not by Mamet (1970) who placed its foraminifera and algal microflora in Foraminiferal Zone 15. Mamet (1970, fig. 4) correlated this zone with the European ammonoid zone Cu IIIα of middle late Viséan age. Jansa *et al.* (1978) added support by stating that there is no evidence in Atlantic Canada for a middle Viséan marine microfauna.

TABLE 4. Distribution of conodonts at localities 5 and 6 (see Appendix), the *Taphrognathus transatlanticus* Zone, area A of von Bitter and Plint-Geberl (1982), south-western Newfoundland, Canada. Identifications by von Bitter and Plint-Geberl (1982). All specimens deposited at the Royal Ontario Museum, Toronto.

Cod 1-1	Cod 1-2	Cod 1-3	Cod 1-4	Cod 1-5	Cod 1-19	Cod 1-20	Cod 1-21	
-	-	-	-	-	-	-	13	Cavusgnathus windsorensis, Sp element
-	-	-	-	-	-	-	3	Cavusgnathus windsorensis, Oz element
-	-	-	-	-	-	-	1	Cavusgnathus windsorensis, Ne element
-	-	-	-	-	-	-	4	Cavusgnathus windsorensis, Hi element
-	-	-	-	-	-	-	1	Cavusgnathus windsorensis, Pl element
3	-	-	-	-	-	-	-	? Bispathodus spp.
11	17	11	2	6	-	5	15	Spathognathodus sp. nov. A
10	-	-	-	26	-	-	5	Spathognathodus campbelli
-	1	12	2	1	-	2	-	Cavusgnathus regularis type, Sp element
-	3	-	1	-	-	-	-	Cavusgnathus regularis type, Oz element
-	1	-	2	-	-	-	-	Cavusgnathus regularis type, Ne element
50	1	15	2	18	3	10	1	Taphrognathus transatlanticus sp. nov., Sp element
2	-	-	-	-	-	7	-	Taphrognathus transatlanticus sp. nov., Oz element
-	-	3	-	-	-	9	-	Taphrognathus transatlanticus sp. nov., Hi element
-	-	-	-	-	-	-	-	Taphrognathus transatlanticus sp. nov., Pl element
1	-	-	-	-	-	3	-	Taphrognathus transatlanticus sp. nov., Tr element
2	-	2	-	6	-	-	-	Unidentified Oz element
10	15	33	4	3	1	37	9	Unidentified Hi element
6	8	2	4	-	-	-	-	Unidentified Pl element
3	4	4	2	-	-	-	-	Unidentified Tr element
2	7	1	-	2	-	-	-	Unidentified Ne element
2	5	2	-	2	-	-	38	Genus and species indeterminate
-	P	-	P	-	-	-	-	? Conodont pearls
2	2	2	2	2	2	2	2	Weight of sample processed (Kg)
1·61	1·91	1·87	1·75	1·76	1·39	1·39	1·48	Weight of sample broken down (Kg)

We suggest that the *T. transatlanticus* Zone (and the lower B Subzone, by extension) of Atlantic Canada is in fact middle Viséan in age. We have already stated that the *T. transatlanticus* Zone is present in the B Subzone of Atlantic Canada and in the S_2 Zone of the Avon Gorge. The B Subzone coincides approximately with Cycle 2 of the Windsor Group (Giles 1981) and this cycle in turn has been 'equated' (ibid., p. 1) with part or all of the Holkerian Stage of Great Britain. The S_2 Zone of the Avon Gorge was correlated with the Holkerian Stage by George *et al.* (1976, p. 11, table 1) who indicated (p. 73) that the base of Mamet's zone 13 is reasonably correlated with the base of the Holkerian. Mamet (1970, fig. 2) showed the base of foraminiferal zone 13 as middle middle Viséan.

We believe that the zone defined by the occurrence of *T. transatlanticus* sp. nov. marks a relatively brief interval of time that may be of considerable importance in correlation. The use of the Avon Gorge as a standard section is considered by some to be problematic in view of considerable non-sequences (Ramsbottom 1973, p. 595). The characteristic fauna of the *T. transatlanticus* Zone has not been reported from the recently defined stages of the British Dinantian. The zone by implication should be present within the Holkerian Stage (George *et al.* 1976) but has not been reported from above the base of the type Holkerian section nor from below the base of the type Asbian section (Ramsbottom 1981).

T. transatlanticus sp. nov., although a species that preferred shallow-water conditions, was apparently not as tolerant of variable salinities as was *C. windsorensis* Globensky. The former consistently defines a narrow faunal zone and occurs in a variety of marine sediments ranging from micritic brachiopod coquinas (Miller Limestone and Maxner Limestone at localities 9, 10, and 11, near Windsor, Nova Scotia) to black fissile shales (Fisher Limestone, locality 12, Miller's Creek, Nova Scotia).

SYSTEMATIC PALAEONTOLOGY

Order CONODONTOPHORIDA Eichenberg, 1930
Superfamily POLYGNATHACEA Bassler, 1925
Family CAVUSGNATHIDAE Austin and Rhodes *in* Clark *et al.*, 1981
Genus TAPHROGNATHUS Branson and Mehl, 1941

Type species. T. varians Branson and Mehl, 1941, by original designation.

Remarks. Taphrognathus was erected to include platform conodont elements possessing a 'median blade' that 'continued into the median trench as a short carina' (Branson and Mehl 1941). A number of later authors encountered specimens transitional in characteristics between species of *Taphrognathus* and those of the genus *Cavusgnathus*. Rexroad and Collinson (1963) and Rhodes *et al.* (1969) called these taxonomic intermediates *Taphrognathus–Cavusgnathus* transitions and Rexroad and Collinson (1963) interpreted them as evolutionary intermediates between the two genera. In recent years, the name *Taphrognathus* has been applied to conodonts for which a subcentral rather than a central blade can be demonstrated (Druce 1969, 1970), or to conodonts with a blade that is not only subcentral in position but clearly joined to the outer parapet (Baxter 1972; von Bitter 1976; von Bitter and Plint-Geberl 1982). *Cavusgnathus*, as redefined by Lane (1967, 1968), does not include species bearing platform elements that are symmetrically paired.

Neither generic category as presently defined is sufficiently broad to comfortably and unequivocally include the new species recognized and defined by us. *T. varians*, the type species of the genus, is known to be 'Highly variable in all aspects of its morphology' (Nicoll and Rexroad 1975, p. 27), and a small proportion of the specimens placed by these authors in *T. varians* were recognized to have the blade in a non-median position. Until the amount of variation exhibited by *T. varians* and other species of *Taphrognathus* is better documented, we hesitate to use another generic category for platform conodonts whose morphology is at variance with the type specimens of the genotype.

The element terminology which is used in the following descriptions is a slightly modified form of that proposed by Jeppsson (1971). The modification involves capitalization of the terms: Sp; Oz; Hi; Pl; and Tr elements. This is consistent with the terminology previously used by the senior author.

Taphrognathus transatlanticus sp. nov.

Plates 17 and 18

Sp element

1969 *Taphrognathus–Cavusgnathus* transitions; Rhodes *et al.*, p. 242, pl. 13, figs. 1–3.
1973*b* Juvenile? *Cavusgnathus–Taphrognathus* transition; Austin, p. 108, fig. 1.1*a*.
1973*b* Ontogenetic stages of *Cavusgnathus*; Austin, p. 108, figs. 1.2–1.4 only.
1976 *Taphrognathus* sp. von Bitter, p. 231.
1982 *Taphrognathus* n. sp. A; von Bitter and Plint-Geberl, p. 197, pl. 3, figs. 1–5, 7.

Oz element

1982 *Taphrognathus* n. sp. A; von Bitter and Plint-Geberl, p. 197, pl. 7, figs. 3, 4, 8, 14.

Hi element

1982 *Taphrognathus* n. sp. A; von Bitter and Plint-Geberl, p. 197, pl. 7, figs. 19, 23.

Pl element

1982 *Taphrognathus* n. sp. A; von Bitter and Plint-Geberl, p. 197, pl. 7, figs. 10, 11, 13.

Tr element

1982 *Taphrognathus* n. sp. A; von Bitter and Plint-Geberl, p. 197, pl. 3, figs. 6, 8.

Material. Holotype ROM 38474; paratypes ROM 38473, 38475; other figured specimens from Canada and those referred to in Tables 3 and 4 are also deposited in the Department of Invertebrate Palaeontology, Royal Ontario Museum, Toronto. Specimens from Great Britain referred to in Tables 1 and 2 are deposited in the British Museum (Natural History) (figured specimens) and the Geology Department, University of Southampton (unfigured specimens). Localities listed in Appendix.

Origin of name. With reference to the occurrence of the species, and the zone it defines, on both sides of the Atlantic Ocean.

Type horizon and locality. Fischells Limestone of Bell (1948). Sampled as Fish-1-1 to Fish-1-5 by von Bitter and Plint-Geberl (1982) (see Appendix). Locality 2, Fischells Brook, south-western Newfoundland, Canada (see Appendix). Section starting at and proceeding downstream from the base of the first major limestone (Fischells Limestone of Bell 1948), north-west of railroad trestle (Canadian National Topographic Series 1:50,000, Flat Bay Map Sheet 12B/7). The type locality corresponds to most, but not all, of locality 5 of von Bitter and Plint-Geberl (1982) and stops at the top of the third carbonate unit above the top of the Fischells Limestone. The uppermost part of the third carbonate unit was sampled as Fish-1-10 by von Bitter and Plint-Geberl (1982).

Diagnosis. A conodont species having an apparatus containing five element types, all of which, with the probable exception of the Tr element, were symmetrically paired. All the elements are small, including the diagnostic Sp or platform element. The Sp element is taphrognathiform and has unornamented sub-parallel parapets. The elements often show a strong but consistent tendency toward either recrystallization of, or overgrowth by, calcium phosphate. This phenomenon is best developed orally, suggesting some type of instability of white matter. Whether the overgrowth or recrystallization took place during or after the life of the species is unknown. All elements appear to have a greater tendency to recrystallization or overgrowths than those of other species, which makes the phenomenon useful in apparatus reconstruction.

Description. Sp element (Pl. 17, figs. 1–8, 10, 11; Pl. 18, figs. 1–10). A generally small element that occurs as both sinistral and dextral elements (Pl. 17, figs. 1, 2), with features that can generally only be demonstrated adequately by scanning electron microscopy. The blade is a continuation of the outer parapet and these two parts are separated from one another by an outer parapet notch. The inner parapet is of equal height to the outer parapet; the inner parapet is slightly shorter and terminates at the anterior trough opening (Pl. 17, figs. 5, 6). The parapets are unornamented although they may be covered with apatite crystals (Pl. 17, fig. 11; Pl. 18, figs. 1, 3–5, 7–10). The sub-parallel parapets are separated by a moderately deep trough which is closed posteriorly by the coming together of the parapets. The posterior end of the platform is pointed and in lateral view exhibits a vertical drop-off (Pl. 17, fig. 4).

The free blade bears up to seven laterally compressed denticles. The maximum number is generally five but, as with other platform conodonts, the blade denticle number is a function of size. The cusp is the largest and most posterior of these denticles and may be either considerably or only slightly larger than the more anterior denticles. The posterior edge of the cusp drops off vertically into the parapet notch mentioned previously. Aborally there is a large slightly asymmetrical basal cavity (Pl. 17, fig. 3). The basal cavity starts at the posterior tip, reaches its maximum width below the cusp, and then begins to be constricted under the blade. Throughout its length it bears a basal groove that reaches its maximum depth in a basal pit under the cusp. The lateral edges of the basal cavity are defined by prominent flaring aprons. These are apparently equally prominent on both the inner and outer sides of the element.

Oz element (Pl. 17, fig. 12; Pl. 18, fig. 14). A laterally compressed, unarched element characterized by abbreviated anterior and posterior bars, the latter being the weaker of the two. The anterior and posterior edges of the bars overhang the more aboral portion of the conodont in a characteristic sinuous fashion (Pl. 17, fig. 12). The short anterior and posterior bars each bear up to three denticles, anterior and posterior to the cusp respectively. The anterior and posterior bar denticles are of differing lengths, the middle of the three often being the longest. This variability in length is the cause of the irregular oral outline of the two bars when seen in lateral view.

Aborally the element bears a moderately large basal cavity that narrows and becomes constricted under the anterior bar. The basal pit under the cusp is the deepest part of the basal cavity and is directed anteriorly. The element is slightly flexed laterally and occurs as both dextral and sinistral elements. It is very similar to the Oz element of *C. windsorensis* Globensky (see von Bitter 1976; von Bitter and Plint-Geberl 1982). The latter species and *T. transatlanticus* sp. nov. rarely occur together in Atlantic Canada and this, as well as the criteria outlined in Table 5, serves to differentiate their Oz elements.

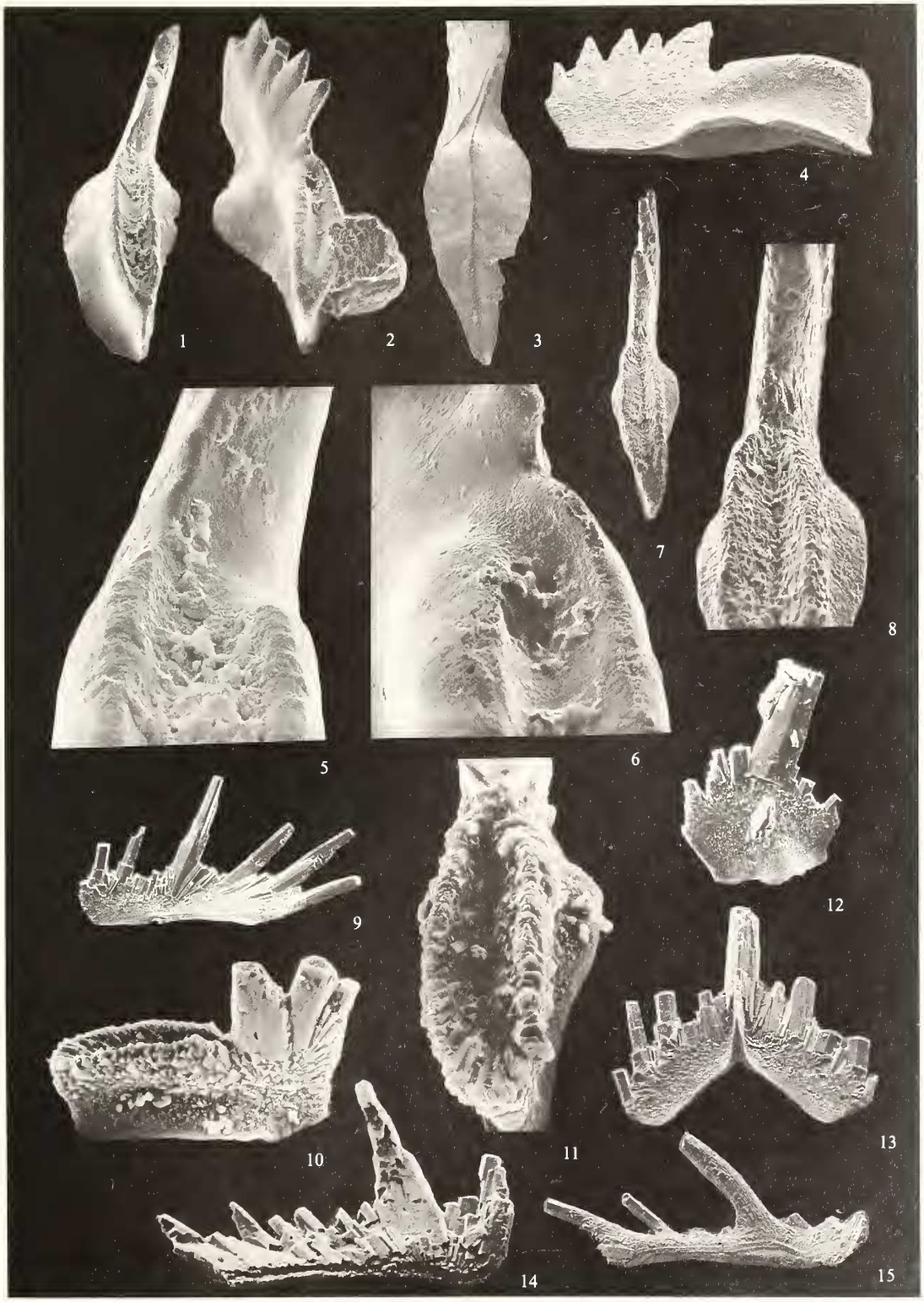
TABLE 5. Morphological characteristics of the Oz elements of *Taphrognathus transatlanticus* sp. nov. and *Cavusgnathus windsorensis* Globensky.

Taphrognathus transatlanticus sp. nov. Oz element	*Cavusgnathus windsorensis* Globensky Oz element
Relatively short anterior and posterior bars	Relatively long anterior and posterior bars
Irregular denticulation with middle of three bar denticles generally the largest	Regular denticulation with up to five denticles gradually and regularly increasing in size toward the cusp
Anterior bar strong; posterior bar weak	Anterior and posterior bars almost equally strong

EXPLANATION OF PLATE 17

Figs. 1–15. *Taphrognathus transatlanticus* sp. nov. Lower Codroy Group, Newfoundland (figs. 1–3, 5, 6, 9–15), and Windsor Group, Nova Scotia (figs. 4, 7, 8), Canada; *T. transatlanticus* Zone, Viséan, Lower Carboniferous. 1, holotype, ROM 38474, oral view of sinistral Sp or platform element, sample Fish-1-1, locality 2, ×235. 2, paratype, ROM 38475, oral view of dextral Sp or platform element, sample Fish-1-1, locality 2, ×220. 3, paratype, ROM 38473, aboral view of Sp or platform element, sample Fish-1-8, locality 2, ×160. 4, ROM 38471, lateral view of Sp or platform element, sample Mi-1-1, locality 9, ×135. 5, 6, ROM 38474 and 38475, detailed views of sinistral and dextral Sp or platform elements, ×1200 and ×1120 respectively. 7, ROM 38472, oral view of ?sinistral Sp or platform element, sample Mi-1-1, locality 9, ×150. 8, ROM 38472, detailed oral view of ?sinistral Sp or platform element, ×390. 9, ROM 38488, inside lateral view of dextral Pl element, sample Corm-1-3, locality 3, ×125. 10, ROM 38485, lateral view of Sp or platform element, sample Corm-1-1, locality 3, ×225. 11, ROM 38485, oral view of Sp or platform element, ×450. 12, ROM 38477, lateral view of Oz element, sample Corm-1-3, locality 3, ×190. 13, ROM 38490, posterior view of Tr element, sample Corm-1-3, locality 3, ×165. 14, ROM 38489, inside lateral view of sinistral Hi element, sample Corm-1-2, locality 3, ×47. 15, ROM 41846, inside lateral view of sinistral Hi element, sample Cod-1-3, locality 4, ×50.

See Appendix for locality details.



VON BITTER and AUSTIN, *Taphrognathus*

Hi element (Pl. 17, figs. 14, 15; Pl. 18, figs. 11, 12). A relatively unarched, laterally bowed element dominated by a large cusp and a large anterior bar denticle. The anterior bar is variable in length depending on ontogenetic stage. Small specimens have only a very short bar whereas larger elements have a longer bar. Longer anterior bars bear three to four denticles while short anterior bars bear one or two denticles anterior to the cusp. The anteriormost denticle is generally the largest. The anterior bar is deflected inward very slightly and may also be directed either orally or aborally slightly. The posterior bar is generally three to four times the length of the anterior bar and bears a series of relatively stout posteriorly inclined denticles. The denticulation of the posterior bar is not noticeably 'hindeodellid' (i.e. consisting of alternating large and small denticles). Rather, the denticles increase in size posteriorly, culminating in the large inclined posteriormost denticle. Aborally a narrow aboral groove (Pl. 17, fig. 14; Pl. 18, fig. 11) that presumably opens into a basal cavity or basal pit under the cusp may be seen in some specimens. This groove may be completely closed and everted (Pl. 17, fig. 15), particularly in mature specimens, preserving only the smallest of basal pit openings.

The Hi element, like the Oz element of this species, can be differentiated from the homologous elements in the apparatus of *C. windsorensis* only with difficulty. The almost mutually exclusive occurrence of the two species in Atlantic Canada and the tabulated characteristics shown in Table 6 helps to distinguish them.

Pl element (Pl. 17, fig. 9; Pl. 18, fig. 13). A rarely preserved, laterally compressed, only very slightly arched element. It is recognized by its association with other elements of the apparatus; by its weakly to strongly inclined cusp approximately one-third to nearly one-half of the distance (measured from the anterior end) between the anterior and posterior ends; by its apparently hindeodellid denticulation; and by its characteristic posteriorly inclined, relatively large (compared with the Hi element) basal cavity. The anterior bar is not noticeably curved

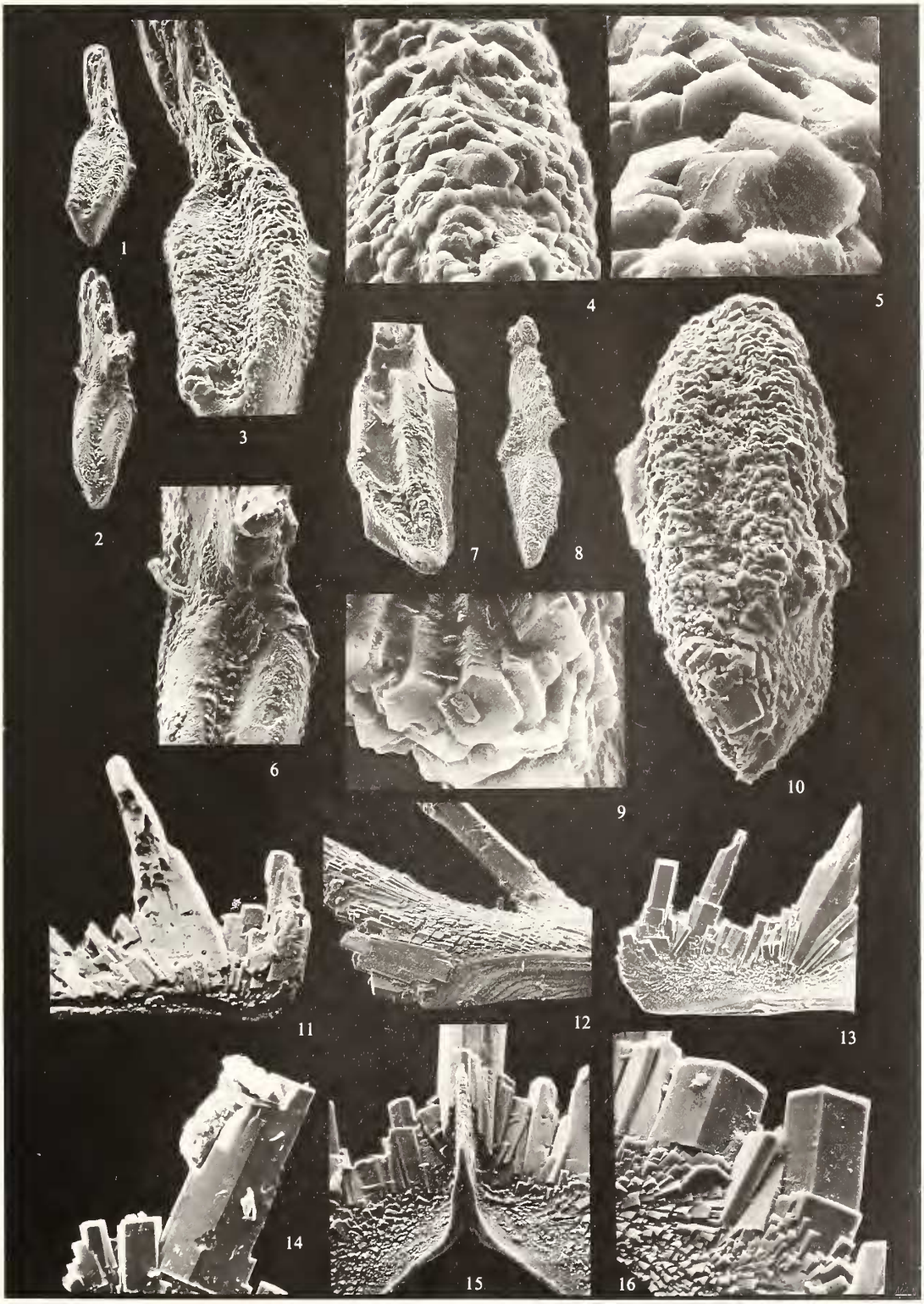
TABLE 6. Morphological characteristics of the Hi elements of *Taphrognathus transatlanticus* sp. nov. and *Cavusgnathus windsorensis* Globensky.

Taphrognathus transatlanticus sp. nov. Hi element	*Cavusgnathus windsorensis* Globensky Hi element
Slight inward anterior bar deflection	Greater inward anterior bar deflection
Large anterior bar denticle	Lacking large anterior bar denticle
Hindeodellid denticulation poorly developed	Well-developed hindeodellid denticulation

EXPLANATION OF PLATE 18

Figs. 1–16. *Taphrognathus transatlanticus* sp. nov. Avon Gorge, U.K. (figs. 1–8, 10) and Lower Codroy Group, south-western Newfoundland, Canada (figs. 9, 11–16) in part showing well and consistently developed recrystallization and/or overgrowth of calcium phosphate; *T. transatlanticus* Zone, Viséan, Lower Carboniferous. 1, BM X 755, oral view of dextral Sp or platform element, sample S53, locality 1, × 125. 2, BM X 756, oral view of ?dextral Sp or platform element, sample S58, locality 1, × 120. 3, BM X 755, detailed oral view of dextral Sp or platform element, × 320. 4, 5, BM X 755, detailed views of outer parapet showing hexagonal calcium phosphate crystals, × 1270 and × 3170 respectively. 6, BM X 756, detailed oral view of ?dextral Sp or platform element, × 300. 7, BM X 757, oral view of sinistral Sp or platform element, sample S54, locality 1, × 75. 8, BM X 758, oral view of ?dextral Sp or platform element, sample S58, locality 1, × 95. 9, ROM 38485, detailed oral view of posterior portion of platform showing well-developed recrystallization and/or overgrowth, × 1480. 10, BM X 758, detailed oral view of ?dextral Sp or platform element showing recrystallization and/or overgrowth (note that blade shown in fig. 8 was broken off during preparation), × 360. 11–16, detailed views of ramiform conodont elements showing calcium phosphate recrystallization and/or overgrowth developed on or toward the oral surface. 11, ROM 38489, anterior end of sinistral Hi element, sample Corm-1-2, × 340. 12, ROM 41846, posterior end of sinistral Hi element, sample Cod-1-3, × 130. 13, ROM 38488, anterior end of dextral Pl element, sample Cod-1-3, × 235. 14, ROM 38487, cusp of Oz element, sample Corm-1-3, × 360. 15, ROM 38490, detail of posterior projection of Tr element, sample Corm-1-3, × 320. 16, ROM 38490, detail of lateral bar denticles, × 615.

See Appendix for locality details.



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laterally whereas the posterior bar is curved inward to a slight but noticeable degree. The anterior bar denticles are directed slightly toward the cusp. Those of the posterior bar are more inclined, become progressively larger posteriorly, and the terminating denticles may be as large as or larger than the cusp. The last feature aids in distinguishing the Pl from the Hi element. Aborally, the Pl element bears a narrow basal groove which opens into the characteristic asymmetrical posteriorly inclined basal pit under the cusp.

This element has been recovered so infrequently (Table 3) that it is difficult to differentiate it from the Pl element of *C. windsorensis*. The element may prove to have been vicarious. However, the fact that such samples as Corm-1-3 and Corm-1-4 (locality 3, south-western Newfoundland) are thought (von Bitter and Plint-Geberl 1982, p. 198) to have contained the component elements of only *T. transatlanticus* sp. nov., and that *C. windsorensis* almost never occurs with *T. transatlanticus* sp. nov. in Atlantic Canada, helps this differentiation. The Pl element of *C. windsorensis* is better known and appears to be more delicate than that of *T. transatlanticus* sp. nov., lacking the latter's large cusp and noticeably large splayed posterior denticles (ibid., pl. 7, fig. 12).

Tr element (Pl. 17, fig. 13; Pl. 18, figs. 15, 16). A bilaterally symmetrical butterfly shaped element possessing a short posterior keel or process. The lateral bars of mature specimens form an angle of approximately 120° with one another. That of juvenile smaller specimens becomes increasingly obtuse, reaching approximately 170°. The lateral bar denticles are recurved, discrete, and number three to four in mature elements. The denticle second from the end is the largest. The lateral bars curve inward, forming a small depression at their junction on the outer side of the conodont. The cusp is triangular in cross-section and is recurved and keeled on the inner side. An undenticulated keel is present at the base of the cusp on the posterior side and in its lower portion forms the upper limit of the sub-triangular basal cavity. The basal cavity varies in size with ontogeny, being larger in mature specimens (Pl. 17, fig. 13; Pl. 18, fig. 15). The basal cavity narrows laterally and becomes a narrow basal groove that disapears one-third to one-half the distance along the lateral bars.

The element is similar to the Tr elements of *C. windsorensis* Globensky and *Hindeodus cristulus* Miller and Youngquist. It is therefore important to note which platform elements are present in any sample containing symmetrical butterfly shaped Tr elements. The characteristics tabulated in Table 7 may be used to differentiate the Tr elements of the three species.

Discussion. The distinctive Sp elements of *T. transatlanticus* sp. nov. occur as small sinistral and dextral elements (Pl. 17, figs. 1, 2, 5, 6; Pl. 18, figs. 1, 3, 7). Associated with these elements in the Avon Gorge (Tables 1 and 2) are platform elements that might initially be thought ontogenetic growth stages of *T. transatlanticus* sp. nov. The first ontogenetic series based on specimens from samples S45 and S49 contains cavusgnathiform elements herein identified as *C. unicornis* Youngquist and Miller, Sp element; these elements are weakly ridged on the outer parapet at all stages of their ontogeny (Pl. 19, figs. 11–18). The inner parapet, however, while still faintly noded in the largest specimen available, is not noded in smaller growth stages. The second ontogenetic series (Pl. 19, figs. 19–28)

EXPLANATION OF PLATE 19

Figs. 1–10. *Cavusgnathus windsorensis* Globensky, Sp elements. Locality 1, Avon Gorge, U.K.; *Taphrognathus transatlanticus* Zone, Viséan, Lower Carboniferous. 1–3, oral views, partial ontogenetic growth series showing nodosity typical of this species, sample S49; 1, BM X 759, × 75; 2, BM X 760, × 72; 3, BM X 761, × 70. 4–6, detailed oral views; 4, BM X 759, × 150; 5, BM X 760, × 145; 6, BM X 761, × 140. 7, 8, inside lateral views, sample S49; 7, BM X 762, × 65; 8, BM X 763, × 68. 9, 10, detailed inside lateral views; 9, BM X 762, × 135; 10, BM X 763, × 130.

Figs. 11–28. *Cavusgnathus unicornis* Youngquist and Miller, Sp elements. Locality 1, Avon Gorge, U.K.; *T. transatlanticus* Zone, Viséan, Lower Carboniferous. 11–14, detailed oral views of ontogenetic growth series showing initial weak ridges and nodes increasing in strength with size; 11, BM X 764, sample S45, × 340; 12, BM X 765, sample S49, × 233; 13, BM X 766, sample S45, × 150; 14, BM X 767, sample S49, × 105. 15–18, overall oral views; 15, BM X 764, × 68; 16, BM X 765, × 60; 17, BM X 766, × 60; 18, BM X 767, × 53. 19–21, 27, 28, detailed oral views of ontogenetic growth series showing initial nodosity developing into stronger ridges with increase in size, sample S49; 19, BM X 768, × 245; 20, BM X 769, × 135; 21, BM X 770, × 135; 27, BM X 771, × 105; 28, BM X 772, × 105. 22–26, overall oral views; 22, BM X 768, × 100; 23, BM X 769, × 68; 24, BM X 770, × 68; 25, BM X 771, × 53; 26, BM X 772, × 53.

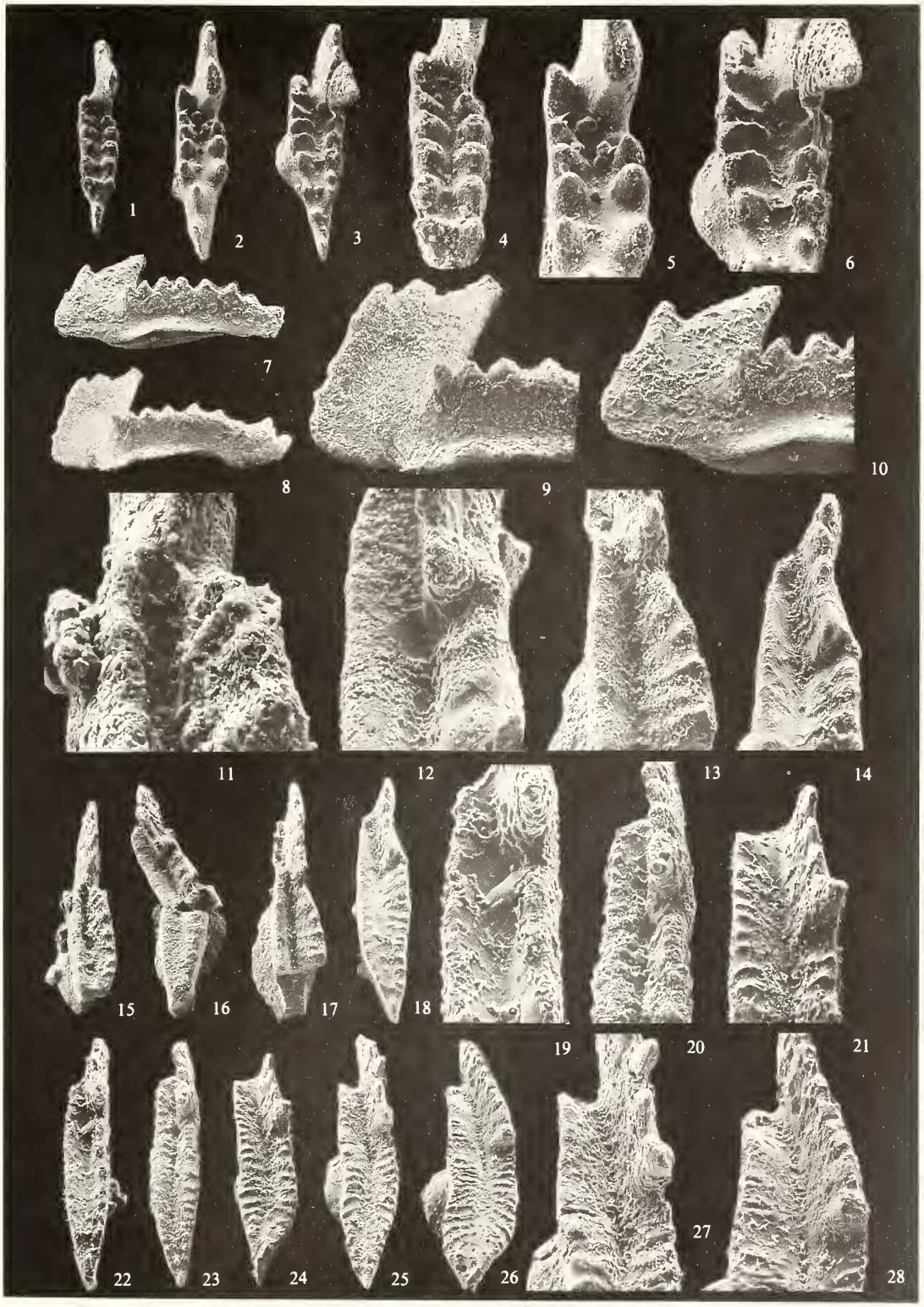

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TABLE 7. Morphological characteristics of the Tr elements of *Taphrognathus transatlanticus* sp. nov., *Cavusgnathus windsorensis* Globensky, and *Hindeodus cristulus* Miller and Youngquist.

Taphrognathus transatlanticus sp. nov. Tr element	*Cavusgnathus windsorensis* Globensky Tr element	*Hindeodus cristulus* Miller and Youngquist Tr element
Undenticled posterior keel present	Posterior keel may bear denticles and may grade into a posterior bar	Posterior keel or posterior bar absent
Cusp triangular in cross-section	Cusp sub-triangular in cross-section	Cusp elliptical to oval in cross-section
Element bilaterally symmetrical	Element bilaterally symmetrical	Element slightly asymmetrical
Discrete non-hindeodellid denticulation on anterior bars	Hindeodellid denticulation on anterior and posterior bars	

from sample S49 are cavusgnathiform elements, again identified as *C. unicornis* Youngquist and Miller, Sp element, whose traverse ridges, although decreasing in strength and length, are still present as nodes in even the smallest specimen recovered (Pl. 19, figs. 19, 22). The nodes in this smallest specimen are much more prominent on the outer bladed parapet. Smaller specimens almost without nodes, and thus intermediate with the largest Sp elements of *T. transatlanticus* sp. nov., have not been found. Note that the largest specimen of the first growth series (Pl. 19, figs. 14, 18) should be compared with the two largest cavusgnathiform conodonts of the second growth series (Pl. 19, figs. 25–28). As in the second growth series, the smallest specimens available (e.g. Pl. 19, figs. 11, 15) do not form convincing ontogenetic intermediates with the largest platform elements of *T. transatlanticus* sp. nov. However, the possibility that the illustrated specimen (Pl. 19, figs. 11, 15) is a sinistral specimen may be an indication of ontogenetic continuity between *T. transatlanticus* sp. nov. and *C. unicornis* (Pl. 19, figs. 11–18).

Cavusgnathiform conodonts identified as *C. regularis* type, Sp element, associated with *T. transatlanticus* sp. nov. have been reported from the Lower Codroy Group of south-western Newfoundland by von Bitter and Plint-Geberl (1982) (Tables 3 and 4). Similar associations have been noted in numerous samples from the Lower Windsor Group at localities in Nova Scotia and Quebec (see Appendix). Ontogenetic transitions between the *T. transatlanticus* sp. nov. Sp element and that of the *C. regularis* type have not been found at any of these localities, further demonstrating the taxonomic distinctiveness of *T. transatlanticus* sp. nov.

The other cavusgnathiform conodont species referred to earlier as being rare in the *T. transatlanticus* Zone of Atlantic Canada, but moderately common in that zone in the Avon Gorge, is *C. windsorensis* Globensky (Pl. 19, figs. 1–10). We believe this to be the first record of this species from Great Britain and to be distinct from *Windsorgnathus windsorensis* (Globensky) of Austin and Mitchell (1975) and Mitchell and Reynolds (1981).

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APPENDIX. LIST OF LOCALITIES

A. *Localities from which fauna of* Taphrognathus transatlanticus *Zone has been recovered and listed in Tables 1–4.* Description of lithologies and sample sites have been deposited with the British Library, Boston Spa, Yorkshire, U.K., as Supplementary Publication No. 14021 (14 pages). They may be purchased from the British Library, Lending Division, Boston Spa, Wetherby, Yorkshire LS23 7BQ. Prepaid coupons for such purposes are held by many technical and university libraries throughout the world.

1. Avon Gorge, Bristol, U.K. Riverside exposure of the uppermost part of *Seminula* Zone and concretionary bed on Leigh Wood side of River Avon at ST 562737 (O.S. Sheet ST 57, 1:25,000). Traverse 9 of Rhodes *et al.* (1969, p. 22, figs. 5, 65, 66); see also Kellaway (1971, fig. 4).

2. Fischells Brook, south-western Newfoundland, Canada (Flat Bay Map Sheet 12B/7, 1:50,000). Section starting at base of first major limestone, the Fischells Limestone of Bell (1948), north-west of railroad trestle and proceeding north-west toward mouth of stream. In part locality 5 of von Bitter and Plint-Geberl (1982).

3. Ship Cove, south-western Newfoundland, Canada (St. Fintan's Map Sheet 12B/2, 1:50,000). Section E of Bell (1948, p. 21). Cormorant Limestone of Bell (1948, p. 22) sampled from apparent top downward; upper contact not exposed.

4. Barachois Brook, south-western Newfoundland, Canada (St. Fintan's Map Sheet 12B/2, 1:50,000). Section is approximately 91 m south of Trans-Canada Highway bridge on west side of brook. Section J of Bell (1948, p. 30); locality 8 of von Bitter and Plint-Geberl (1982). Barachois Limestone of Bell (1948) sampled from the apparent base upward; contact with underlying beds not exposed.

5. Codroy, south-western Newfoundland, Canada (Codroy Map Sheet 11O/14W, 1:50,000). Section D of Bell (1948, p. 18); Lower Codroy Section of Baird and Cote (1964, p. 517); locality 11 of von Bitter and Plint-Geberl (1982). Thickness of strata over and underlying carbonate units taken from Baird and Cote (1964, p. 517).

6. Woody Cove, south-western Newfoundland, Canada (Codroy Map Sheet 11O/14W, 1:50,000). Section immediately south of outlet of Woody Head Brook. In part section D of Bell (1948, p. 17) and the upper part of section described by Baird and Cote (1964, p. 517). In part locality 2 of von Bitter and Plint-Geberl (1982); refer to their fig. 2 for position of samples.

B. *Other localities in Atlantic Canada from which fauna of* Taphrognathus transatlanticus *Zone has been recovered.* Deposition information same as in Appendix A.

7. Johnstown, Richmond County, Cape Breton Island, Nova Scotia, Canada (Grand Narrows Map Sheet 11F/15, 1:50,000). 7A, at beach on Bras d'Or Lake. 7B, a brook section on the south-east side of the road approximately 1·2 km south-west of the cemetery and church at Johnstown.

8. Port Hood Island, Inverness County, Cape Breton Island, Nova Scotia, Canada (Port Hood Map Sheet 11K/4, 1:50,000). Units B_0 and B_1 of von Bitter (1976) sampled. Section studied by Stacy (1953), Schenk (1969), and von Bitter (1976).

9. Windsor, Hants County, Nova Scotia, Canada (Windsor Map Sheet 21A/16 East Half, 1:50,000). Section 2 of Bell (1929, p. 47). Miller Limestone of Bell (1929, p. 47) sampled.

10. Avondale (Newport Landing), Hants County, Nova Scotia, Canada (Wolfville Map Sheet 21H/East Half, 1:50,000). Shore section on Avon River discussed by Bell (1929, p. 47) and studied and mapped by Waring (1967). 10A, the Miller Limestone, exposed a short distance north-east of the wharf at Avondale. 10B, the Belmont Limestone of Moore (*in* Geldsetzer *et al.* 1980), of which 1 m $\pm$ is exposed at Avondale.

11. Windsor, Hants County, Nova Scotia, Canada (Windsor Map Sheet 21A/16 East Half, 1:50,000). Section 2 of Bell (1929, p. 47). Maxner Limestone of Bell (1929, p. 47) sampled.

12. Miller's Creek, Hants County, Nova Scotia, Canada; gypsum quarry operated by Fundy Gypsum Co. (Windsor Map Sheet 21A/16 East Half, 1:50,000). Stop 8 of Geldsetzer *et al.* (1980). The Belmont and Fisher limestones were sampled from their apparent bases upward in the south wall of the quarry.

13. Île Alright, Magdalen Islands, Quebec, Canada; east shore of island, north of Cap Alright and Ansé Firman (Île du Cap-aux-Meules Map Sheet 11N/5, 1:50,000). Locality D of Plint-Geberl (1981).

14. Île du Cap-aux-Meules, Magdalen Islands, Quebec, Canada; west part of island, 2 km east of Point Herisée, 2 km south-east of Cap-au-Trou (Île du Cap-aux-Meules Map Sheet 11N/5, 1:50,000). Locality E of Plint-Geberl (1981).

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